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UNITED STATES PATENT APPLICATION FOR:

METHOD FOR FLUORESCENT LAMP DIMMING CONTROL

Background of the Invention

A means of varying fluorescent light intensity is required in certain applications, such as in avionics, especially at low ambient light levels. Currently, high-frequency switching supplies are used, although at low brightness levels such supplies suffer from non-uniform brightness across the display and flickering caused by arc instability. Superior results have been achieved by utilizing separate supplies for high and low brightness ranges, and switching between them to obtain the desired level of brightness.

Brief Description of Drawings

Figure 1 is a schematic diagram of a power supply for a fluorescent lamp;

Figure 2 is a schematic diagram of a voltage-based low brightness supply;

Figure 3 is a waveform diagram of the output of the voltage source in the circuit of Figure 2;

Figure 4 is a schematic diagram of a current-based low brightness supply;

Figure 5 is a schematic diagram of a configuration of the voltage-based low brightness supply of Figure 2;

Figure 6 is a waveform diagram of drive signals for the low brightness supply of Figure 5;

Figure 7 is a schematic diagram of an implementation of the voltage-based low brightness supply of Figure 5;

Figure 8 is a schematic diagram of a configuration of the current-based low brightness supply of Figure 4; and

Figure 9 is a schematic diagram of an implementation of the current-based low brightness supply of Figure 8.

Description of the Invention

A power supply for a fluorescent lamp is shown in the schematic diagram of Figure 1. A fluorescent lamp 10 is powered by two power supplies: a high brightness supply 30 and a low brightness supply alternately connected through a relay K1. The high brightness supply 30 generates an output voltage that will ignite the gas in the lamp 10 so that it produces its normal level of brightness. If a lower level of brightness is desired, the relay K1 switches, connecting the low brightness supply 40. The voltage level of the low brightness supply 40 is below the ignition voltage and therefore the gas in the lamp 10 will not ignite but rather operates in the glow mode or glow discharge mode. Thus, the lamp 10 is switched back and forth between the two supplies as necessary to achieve the brightness desired.

A low brightness power supply and a lamp are shown in Figure 2. There, an ideal voltage source v having a source resistance R_S drives the lamp 10. A suitable waveform for the voltage source output is shown in Figure 3. Here, the waveform is a bipolar pulse-width modulated square-wave. In the example shown in Figure 3, the pulses begin at full width per half cycle (i.e., 100% duty cycle), but are only half of that width after the first three cycles, signifying a change in brightness. By varying the pulse width, the RMS voltage applied to the lamp 10 and, therefore, the observed

intensity of the lamp 10 similarly varies. Other types of waveforms could be employed (e.g., triangular, sawtooth, sinusoidal). Further, the pulse widths could be varied at the leading or trailing edge.

The constant-current equivalent of Figure 2 is illustrated in Figure 4. There, a constant current source I drives the lamp 10. The same waveform used with Figure 2 can be employed here, the vertical axis being current i instead of voltage v.

A configuration of the voltage-based low brightness supply of Figure 2 is shown in Figure 5. In this circuit, a voltage source V_{DC} is alternately connected to one side or the other of the lamp 10 by switches S_1 and S_2 controlled by voltage generators v_1 and v_2, respectively. These generators produce complementary (180° out of phase) pulse-width modulated square wave signals v_1 and v_2, with duty cycles varying from 0 to 100% (100% being the full half-cycle pulse width) in a frequency range of 60-400 hz. Satisfactory results have been obtained at approximately 100 hz. Typically, the generators are tied to a synchronous clock. Examples of the drive signals are shown in Figure 6. Of course, other waveforms and frequency ranges could be employed.

A more specific implementation of the low brightness supply of Figure 5 is illustrated in Figure 7. The connections to the high brightness supply are omitted for clarity but it should be understood that such a supply could be used with this circuit.

Each side of the lamp 10 is connected to the junction of a load resistor R_1 or R_2 and a switching transistor Q_1 or Q_2. The resistors are chosen to insure that the lamp 10 operates in the glow mode for a given supply voltage. Assuming a supply voltage V_{DC} of 400 volts, a desired lamp voltage of 200 volts, and a lamp resistance of 100K, the load resistors of 100K can be employed. Other voltages and values can be chosen to suit the components and desired design criteria.

When the switching transistors are off, both terminals of the lamp 10 are sitting at the supply voltage V_{DC}. The gates of the switching transistors Q_1 and Q_2 are driven by signals v_1 and v_2, respectively, the duty cycles of which are varied to achieve the desired brightness level.

The circuit in Figure 7 uses a voltage divider of a load resistor R_1 or R_2 and the internal resistance of the lamp 10 to provide a set voltage at the lamp 10 and in turn a predetermined current through the lamp 10. The diode D prevents the source voltage of either Q_1 or Q_2 from going negative and prematurely turning the other transistor on while the resistor R_C limits the current drawn by the parasitic capacitance of the switching transistors.

A configuration for the current-based low brightness supply of Figure 4 is shown in Figure 8. The lamp 10 is driven by a constant current source I in alternating opposite directions by switches S_1 and S_2 controlled by voltage generators v_1 and v_2, respectively. An implementation of the circuit of Figure 8 is shown in Figure 9. The lamp 10 is flanked on each side by a buffer (Q_1 and R_1, or Q_2 and R_2) and a source-follower (Q_3 and R_3, or Q_4 and R_4). The buffers are driven by the voltage generators v_1 and v_2. The current through the lamp 10 is determined by the gate voltage of either Q_1 or Q_2, less the gate-to-source drop, divided by the value of the load resistor R_L. Assuming a gate input voltage of 12 volts and a gate-to-source drop of 3 volts, and value of 2.4 K for the load resistor R_L, the current will then be 3.75 ma.

The diodes D_1 and D_2 protect the gate-source junctions of Q_3 and Q_4 by preventing the voltage across those junctions from reaching an excessive level whenever the transistors are switched.

Similar to the diode in Figure 7, diode D_3 prevents Q_1 and Q_2 from turning on as a result of the source voltage going to less than zero when the drive is zero. The

series combination of C_1 and R_5 has a short time constant and provides a charging circuit for the parasitic capacitances of the transistors Q_1 and Q_2. The arrangement in Figure 9 dissipates less power than the voltage-based circuits because the circuit uses current control to vary the brightness of the lamp 10, instead of large voltage drops across load resistors.

In operation, the circuit of Figure 1 can provide variable light output over a broad range. At the high end of brightness, the high brightness supply 30 can be configured to provide sufficient energy to the lamp 10 to produce a variable light intensity from a maximum value, determined by the characteristics of the lamp 10 and voltage applied to the lamp 10, down to some minimum value. The lamp in this circumstance operates mostly in the arc discharge mode or region, and perhaps partially in the glow discharge region. After a transition, e.g., by switching the relay K1, the low brightness supply 40 provides energy to the lamp 10, maintaining the voltage on the lamp 10 to a level that keeps the operation of the lamp 10 in the glow discharge mode or region. When powered by the low brightness supply 40, the lamp's output is more uniform at very low luminance levels.

If desired, the components, voltages, duty cycles, and other parameters can be chosen to provide an overlap between the high and low brightness ranges. A slight overlap between the high and low ranges will avoid any discontinuity in brightness.